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August 31, 1995

Document Control Desk U.S. Nuclear Regulatory Commission Washington, D.C. 20555

ATTENTION: MR. T. R. QUAY

SUBJECT: AP600 PCS DESIGN BASIS ACCIDENT "ROADMAPS"

Dear Mr. Quay:

The attachment to this letter provides several tables which were developed to assist the ongoing review of the AP600 Passive Containment Cooling System design basis analyses. The tables outline the PCS DBA methodology and have been revised to reflect items discussed in recent meetings between Westinghouse and the Containment Systems and Severe Accident Branch. This document was prepared in response to an NRC staff request and is intended to assist the review currently underway by the Containment Systems and Severe Accident Branch.

Please contact me on (412) 374-4334 if you have any questions concerning this transmittal.

Brian A. McIntyre, Manager

Advanced Plant Safety and Licensing

/nja

Attachment

- cc: D. Jackson, NRC
 - J. Kudrick, NRC
 - E. Throm, NRC

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N. J. Liparulo, Westinghouse (w/o enclosures/attachments)

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Module	PIRT Phenomena	Ranking for Containment	AP600 BCs or Phenomena Models	Test Bases	Report Submitted to NRC	Report Conclusions	Applicability of LST with Respect to Phenomena	Validation of Modeling Method and/or WGOTHIC	Use of Validation Results in this Evaluation Model	How Uncertainty is Handled
[Volume	A. Multi-component Compressible Gasses	Η	Gas constituents in the governing equations	All tests analyzed with WGOTHIC	Complete NTD-NRC-94-4260 Enclosure 1: GOTHIC Technical Manual describes governing equations Enclosure 2: GOTHIC User's Manual describes how to invoke various gasses Enclosure 3: GOTHIC Qualification Report provides large database of tests with air, hydrogen, and heliuze NTD-NRC-95-4462 EPRI Report RA-93-10, GOTHIC Design Review, Final Report WCAP-14382 validates WGOTHIC with separate effects, integral tests with steam and air, and holiuum	Effects of multicomponent compressible gasses are correctly included in governing equations	LST includes air and steam, and helium	WGOTHIC has been validated with the LST	Governing equations in WGOTHIC are a valid representation of compressible, multicomponent gas behavior Maximum Technical Specification pressure used in conjunction with 0% relative humidity.	Rounded
	B. Buoyancy	н	Bucyancy forces are included in the lumped parameter junction governing equations	LST internal boouyant flows Hugot toets Siegel & Nortis toets	Complete WCAP-14326. Separate effects test WCAP-14382, for integral tests	Lumped modeling overmixes noncondensibles above operating deck thereby reducing hear removal from vessel when PCS is dominant Distributed parameter modeling shows good agreement with 550 node LST model. Modeling of buoyancy and entrainment is acceptable.	Steam injection point elevation and direction effects tests were performed LST has prototypical buoyancy driving forces and covered the range of Froude numbers for LOCA	WGOTHIC has been volkdated with the LST	Mixing and strasification- menting from buoyancy- driver. Bow will be studied in the WGGPUHC Applications WCAP See boxes for line IVA.	Semitivity to mining will be provided in applicatione WCAP Bounded

Table 1: PIRT Application to Evaluation Model: Inside Containment - All phases

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Module	PIRT Phenomena	Ranking for Containment	AP600 BCs or Phenomena Models	Test Bases	Report Submitted to NRC	Report Conclusions	Applicability of LST with Respect to Phenomena	Validation of Modeling Method and/or WGOTHIC	Use of Validation Results in this Evaluation Model	How Uncertainty is Handled
	C. Flow Field Stability or Stratification	L	Mixing within the containment upper regions and mixing between the upper and lower portions of the containment	LST	NTD-NRC-95-4459, Stratification and Mixing Effects on AP600 Passive Containment Cooling System DBA WGOTHIC Applications Document ACRS T/H Subcommittee Meeting, March 29-30, 1995 (to be documented in letter report)	Blowdown is the same as standard plants. Long-term LOCA is driven by buoyant plume and LST covers range for AP800. MSLB is well mixed due to high velocity jet. Distributed parameter modeling shows good agreement with 550 node LST model. Modeling of buoyancy and entrainment is acceptable.	Upper and lower regions of containment represented in the UST	WGOTHIC model has been validated with the LST	Mixing and stratification- resulting from buoyancy- drives flow will be studied in the WCOTHIC- Applications WCAP See boxes for line IVA	Semicircly to arising and break size will be provided in applications WCAP <i>Bounded</i>
II. Surface	A. Liquid Film Heat Transfer	м	Thermal conductivity of liquid film for film temperature drop	Chun & Seban Wisconsin Condensation Tests	Complete NTD-NRC-94-4100, Enclosure 2 "Liquid Film Model Validations" WCAP-14382 §2	The Chun and Seban data provides a basis for film thermal conductivity.	Internal and external liquid film effects are represented in the LST	All validation performed with WGOTERC includes the small effect of film temperature drop	Nominal wavy-laminar and turbulent Chun and Seban correlations used as appropriate	Negligible effect since resistance across film is small part of total resistance
	B. Liquid Film Stability/Coverage	L	Condensation on the interior surface of containment	LST Wisconsin Condensation Tests	WCAP-13307 LK. Hubtininemi, "Condensation in the Presence of Noncondensit-le Gas: Effect of Surface Orientation," Ph.D. Thesis, Univ. Wisconsin, 1992	Internal films are stable since containment shell slope is in excess of 1°. Droplet formation improves mass transfer	Prototypical surfaces included in the LST Separate effects studied in Wisconsin Condensation Tests	WGOTHIC model has been validated with the LST	Shell slopes modeled with WGOTHIC exceed 1' Condensate on containment is returned to the IRWST Benefits of droplet formation neglected	Bounded
	C. Liquid Film Enthalpy Transport	м	Liquid film energy conservation equation	LST Wisconsin Condensation Tests	Complete WCAP-14382 §2.4, 2.5 show equations for liquid film WCAP-14190	Subcooling is negligible compared to energy transported to liquid field	Prototypical surfaces included in the LST Separate effects studied in Wisconsin Condensation Tests	WGOTHIC model has been validated via the LST and Wisconsin Condensation Tests	Temperature profile through film considered in solution	Negligible, film is at or near saturation temperature

Table 1: PIRT Application to Evaluation Model: Inside Containment - All phases

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Module	PIRT Phenomena	Ranking for Containment	AP600 BCs or Phenomena Models	Test Bases	Report Submitted to NRC	Report Conclusions	Applicability of LST with Respect to Phenomena	Validaties of Modeling Method and/or WGOTHIC	Use of Validation Results in this Evaluation Model	How Uncertainty is Handled
	D. Free Convection Heat Transfer	L	McAdams Fiat Plate Correlation Mixed Convection	LST	WCAP-14190 page 2-7 WCAP-14326 page 4-1 WCAP-14382 §8	Convective heat transfer is not significant in comparison to mass transfer	Prototypical internals Range of validation defined in WCAP- 14382 §9.2	WGOTHIC model has been validated with the LST	A conservative bias of 0.741 times the nominal correlation is used	Bounded by conservative bias
	E. Forced Convection Heat Transfer	L	Lumpsd - Not modeled Dutribusd - Rat plate forced convection, mixed-convection	LST	WCAP14190 page 2-7 WCAP-14326 page 4-1 WCAP-14382 58	Convective hear transfer is tox significant in comparison to mass transfer	Prototypical internals Range of validation defined in WCAP- 14382 §9.2	WGOTHIC model has been validated with the LST	Lumpad-Forced convection heat transfer not considered Distributed - Nominal flas- plate-correlation	Lumped - Bounded by neglecting forces convection Distributed Bounded by code- uncertainty
	F. Radiation Heat Transfer	L	Not modeled	LST	WCAP-14190 page 2-8	Temperature differences within containment are small enough that radiative heat transfer is low	Prototypical internals and temperature driving forces modeled in LST	WGCTHIC modeling of LST neglected radiative heat transfer	Not modeled	Bounded
	G. Free Convection Mass Transfer	н	Lumped-Heat and mass transfer analogy based on McAdams flas plate beat transfer correlation Distributed - Meat and mass transfor analogy using the mixed correction correlation	LST Wisconsin Condensation Tests	WCAP-14190 page 2-8 WCAP-14326 §3.8, 3.9, 4.3 WCAP-14382 §4.3, 8.2	Mass transfer conservatively biased mean=0.983 σ =0.187	Prototypical internals and temperature driving forces modeled in LST Range of validation defined in WCAP- 14382 §9.2	LST internal data as a separate effect Wisconsin Condensation Tests	A conservative bias of 0.741 simes the nominal correlation is used	Bounded by conservative bias
	H. Forced Convection Mass Transfer	L	Lumped - Not modeled Distributed - Heat and most transfer analogy- based on flat plates foreed convection in the mixed convection. correlation	LST Wisconsin Condensation Tests	WCAP-14190 page 2-8 WCAP-14326 §3.8	Mass transfer conservatively biased mean=0.968 σ=0.203	Prototypical internals and Froude numbers modeled in LST Range of validation defined in WCAP- 14382 §9.2	Lumped - Validated WCAP- 14382 §8 Dominant only during first seconds of LOCA transient Distributed - Dominant only- during first seconds of transient	Lumped - Not modeled Distributed - Mixed convection correlation combining free and forced convection with a conservative bios	Bounded by neglecting forced convection

Table 1: PIRT Application to Evaluation Model: Inside Containment - All phases

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III. Solids	A. 1-D Transient Conduction Heat Transfer	н	GOTHIC conductors used to model internal heat sinks include a 1-D conduction solution	CVTR LST with internal heat sinks	NTD-NRC-94-4260 "GOTHIC Containment Analysis Package, Version 3.4e, Volumes I-111," Volume 1, §6 describes the I-D conduction solution used. WCAP-14382 provides validation with LST	Use of Uchida with 1-D conductor for internal heat sinks is conservative and consistent with SRP guidelines	Internal LST heat sinks are modeled using GCTHIC conductors with Uchida for condensation	WCAP-14382 shows validation results with internal heat sinks modeled with Uchida	SRP grudelines are an acceptable approach. Conservatively bounded material properties are used for AP600 internal conductors. Surface area and volume of internal heat sinks are conservatively underestimated.	Bounded

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IV. Inter- Module	A. Convection	-	Governing for lumped p A volumes connecteu with junctions and connectio-mode connectio-mode distributed parameter	LST	NTD-NRC-05-4459, Stratification and Mixing Effects on AP600 Passive Comainment Cooling System DBA WCAP-14190 §9 WCAP-14190 §9	Fr scaling shows MSLB expected to be well mixed Flow area nerstriction to evoluation nodel limits stream access to below deck during short MSLB rulenses Lumped - Dvermiting penalities beat and mass transfer when PCS is dominant (LOCA dominant (LO	Applicable to above deck circulation and heat and mass transfer correlation validation LST has been used to develop retronate for bounding approach on micing	Mixing hased towerd worst case for each accident A sensitivity using nominal fow area in the AP000 will powared in the CAP to applications WCAP to quantify conservative bias.	Restrict mixing between apper and kwer regions of containment when mixing is a hentifi (LOCA second peak)	Bounded by haaring mitting in conservative direction for each accidere

post-bio

Table 1: PIRT Application to Evaluation Model: Inside Containment - All phases

Moduie	PIRT Phenomena	Ranking for Containment	AP600 BCs or Phenomena Madels	Test Bases	Report Submitted to NRC	Report Conclusions	Applicability of LST with Respect to Phenomena	Validation of Modeling Method and/or WGOTHIC	Use of Validation Results in this Evaluation Model	How Uncertainty is Nandled
	B. Conduction	н	Climes include 1-D conduction model used for conduction through containment shell	Comparison to theoretical solutions	Complete. WCAP-14382 §2.5 shows the governing equation and discretization for 1-D conduction	The 1-D conduction model is correctly programmed into WGOTHIC	I-D conduction used to model heat transfer through the LST shell, which neglects the additional heat removal by azimuthal conduction from dry to wet surfaces.	WCAP-14382 §4.1 contains validation of the 1- D conduction equations in Clime subroutine	1-D conduction equation is part of the Clime subroutines used for heat transfer through the shell. Effects of degradation of inorganic zinc paint are included in material properties. Conservative material properties used. Using 1-D conduction conservatively neglects azitauthal conduction from dry to wet stripes.	Bounded
	C. Form and Friction Losses	L	Inter-compartment losses	Standard experimentally based loss coefficients	WCAP-14382 §6.0 describes methods used to model LST	Use of standard loss coefficients through grating is validated	Simplified representation of lower compartments	See IVA.	Restrict mixing between upper and lower regions of containment when mixing is a benefit. Increase mixing when it is a penalty. (See IVA.)	Bound effects of mixing

Table 1: PIRT Application to Evaluation Model: Inside Containment - All phases

Table 2: PIRT Application to Evaluation Model: Outside Containment - LOCA - All Phases

Date last modified: August 28, 1995

How Uncontaining in Haundhol	Activity of the second se	Neurinel less aceditates la work. Weak aemotholo to lass coefficients Conserventes to lass of the less possible de arrokates for stati up connerre.
Use of Validation Resolts in Evaluation Medal	Governing aquations in WGOTHIC cars to valid representation of cars to valid representation of botanics. Radio Spec value of annimum Tach Spec value of environment temporations is that boundary condition in WGOTHIC models.	The actiant amounts is moduled with pressure bounds or control are the interact outer, such that the proposed 4P is a sequelate the Thus, the intelli amounts at these is connected with interaction downword in the product of downword in the amounts beam of the amounts.
Valdation of Modeling Method andro WGOTHIC	WCAP-14.882 provides validation of external arrendus modelling methods.	WBOTHIC has been validated with LST with natural convection stridge an antibat flows in WCAP 14582 §S. 8. 7. 8.
Applicativity of LST with Respect to Phenomenon	LST includes all abarn, and helium.	All 7 beautive and 7 confirmating. LST to the HMRF program were non with the lan off. The LST provily test 214.1 (fain off) has been used for validation.
Report Conclusions	Effects of multi- component compressible games are convering equations,	The addremal annubus predictions provide compartients to researchistiger can be assertiating at assestiated annutation can assestiated and bit of a sparatin affacts but any orbitated fore are validated in the fore are validated in the fore are validated.
Report Submitted to MPC	Complete NTD-MTC-34-400 NTD-MTC-34-400 Encloses 1: GOTHIC Trathetical Manual Encloses 2: GOTHIC Users Manual Encloses 2: GOTHIC Users Manual Encloses 3: GOTHIC Users Manual Encloses 3: GOTHIC Users Manual Encloses 3: GOTHIC Users a support provides a large database of tests with at- whythogen, and helium WCAP 1:480 withdates WGOTHIC Design Review, Final Report WCAP 1:480 withdates WGOTHIC atth erg: and helium gases. Mentinghouse will an and integral tests with steem, at: and helium gases. Genetisme will an and integral tests with steem. Weathinghouse will an and a advected provides a mark the comes of supportational anew.	Complete WCAP:14382 §7 2.2 Identifies the relevant protein and LST whith an off to support actimited arrentia modelling. WCAP:14386 § 3.1.3.3 WDD.MRC.94.4089 WMRC.7CS Meaning MMRC.7CS Meaning MMRC.7CS Meaning MMRC.7CS Meaning Underm and nonuntificial and incrinal deby protection and nonuntificial and incrinal deby tion with the contribution and incrinal deby tion with the contribution
Test Bases	All heats annityted with WOOTHAIC	1.57 without fan nanning manning
APBOC BCs or Phanomena Meddels	Gan contributions in the governing equations	Buoyancy forces are included in the landed parameter growthins equations
Rentking for Risearth Enternal Flow Path	I	I
PIRT	1. Stateba Victures A. IAAE components present	B. Buoyancy

is Handled	hughgha alloc Waak servelikity be anthroat loos optication to pressure is not pressure is not pressure is pressure is extended the	hughghis afted	Neghtytes effect	borned
Use of Valkatitoon Reeruits on Evaluation Model	Esternal flow path is modelled as	Neghtytele effect on answers	Assumption of no recircutation due to these affects has negligible impact on pressure prediction	Assumption of no vitral is bounding for pressure prediction
Valdation of Moodling Method and/or WGOTHIC	The divencionne free area is large to act a submothing to act as a meanorie are analyzed at the set of a set of the set of t	Ethert of tog neglected in WGOTHIC models	Externel pressure boundary condition is unscheded for these effects	External pressure boundary confilient is unartiparted for these effects
Applectably of LVT with Respect to Phancomanon	Nuk Successful moduling of the setternal annuku with a 10 flow path shows ability of 10 model k, peedid nise phonomenu.	Database consistent with AP000 aspectations for external annulus conditions.	LST was run in no-wind (~5 mph) conditions	Not application
Report Conclusions	Potential for local metrodation +r demonstrate and demonstrate and generating anong how is negligible since there is negligible since there is necessarily of demonstrate is the demonstrate is the demonst	Justification for meglecting ethod of log in translas operate affect of radiation operate by og in APRO has a ranglightle affect on the amounts all translation and overetimation the battle.	Cuantification of potential for restructuation of entiment and thermolysis statistical attractions to statistical attractions to statistical bounding these gaves bounding accounterion bounding atoward no specificant containment prostructure affect.	Ouclifiating flows for wood case schw with iterat conficient scjothy interview inset remonal conficients team on and the removal best removal.
Report Submitted to MISC	Complete INTDARD: 95.4414 INTDARD: 95.4414 MCARP.14190; Section 7.2 and 7.3 provide memorium and aways vacing to be path for anodas. Be path for anodas. La los based Applications Report La los based Applications Report La los based and anomal delay films. See block on film above for ices coefficient study neutifi.	Complete NTD NRIC pix 4100, Enclosure 1 Transferon Hear Transfer Throngh Fog in the PCCS Ar Gay"	Complete KITD-ARE-Set-4166 -XPE00 Containmont Planne inveedigation*	Completes NTD-MRC -95-4467 "Analysis of AP900 Wind Transit Tonting to PCS Heat Ramonal"
Test Bases	 I.S.T. rine External flow peth S.P. test peth and Disput and Monte Naged and Monte Naged 		Literature	Wind funnel tents
APato BCs or Phanomens Models	Edward from path is a 10 hydraudio model	Fog in semitia	Effect of end- induced net- net-collafor and attrocphera is attrocphera is approved	Effect of wind: induced turbulences is neighborhol
Rentering to Reserve				
PIRT Phenomenue	C. Flow feel stability is statilitation			

How Uncertainly a Handled	Nuglights affect time metatross acreat fan 4 metatros.	1
Ure of Valdation Results in Evaluation Model	Naminal Chun and Saban correlation is used, accounting for wary londing and behavior legist lines.	The validation connected as write connection and a surface provide the contribution of the PCS CBA Evaluation Model. Bounding minimum water connecto textions are used
Valitation of Modelling Method and/or WCATHIC	All velicitation performand with WIQOTHIC includes the small effect of liths temperature drop.	Water coverage is an input build with a high build with a coverage is and by protocol of the weather a suad by under a suad by the under a suad by the under a suad by the analysis of the under a suad by the under a suad by the analysis of the under a suad by the subset of the under a subset of the under
Applicability of LST with Respect to Phenomenon	Internal and entimed liquid thin afterts are represented in the LST	Headed LST data has been used to assess heat flor affection. In coverage finitions on the LST were used as input boundary conditions for the boundary condition next to weoclass with test data.
Reg	The Chen and Soldern data provides a transit for tim thermal conductivity. The fight film. Lergenstrue drop is small	Tests with aretice onto surfaces up to 2465 authored delay, even aboved delay, even authored delay, even authored delay, even authored delay, even authored become films dynot. When are heated the dynot. When are heated authored has bear beared delay from 20 odd. Mi authored has bear beared data and heated delay from 20 odd. Mi authored has bear working and adversaria and a strongal bear and a strongal bear and a strongal bear and a strongal by a strate and point the antibute and the antibute antibute the antibute and the antibute and the antibute and the antibute antibute the antibute and the antibute antibute the antibute and the antibute antibute the
Report Submitted to NRC	Complete MID MRC At 4100, Enclosure 2 "Liquid Film Model Validation" WCAP 14382 §2 Sociling septements all discursest sensitients dativation of sensitiences balance	Compiles WCAP-12066, pp.1 WCAP-12066, pp.1 McMP-0504.000 Setting for the APPO Passive Constituents for the APPO Passive Constituents Setting File Plov Converge Methodology, Incidenting Setting to 534 and 173 of hourings SSAR methods to 344 and 173 of hourings SSAR persetting to 544 and 173 of hourings SSAR persetting to 544 and 173 of hourings SSAR persetting to 544 and 173 of hourings SSAR in performantion on any clin in performant in performantion on any clin in performant SSAR Tion
Test Bases	Ohm and Settern	 Full seaths, cold 16 sector trees Hou LST measured converge Weeker argonation tests
APROD BCs or Phenomena Models	Thermal conductively of loyad then to the temperature strip.	Shell were converge hystolica and applied from the
Ranning for Risso ⁽²⁾ Ensemal Risse Path	3	I
PISIT Phenomenon	R. Northle Stateon A. Ligget the hear transfe	B. Lapide fem establishi conversion

How Uncartant, is Handlac		Nagligation adhect since mechanism acrossite for only AP000 heat removal.	Recent
Use of Validetion Reeufic in Evaluation Model	Second the Jodan surface thereperature dates and increases which here there address not increases which are in the there address the number of number three address the address in the three address the address in the determine address three and the address address three ad- three address three address three three address three address three address three address three address three address three address three addr	WEOTHEC uses an appropriate set of generating equations for Argold Rim. Subcooling accounts for a small faction (-5%) of the APS00 held removel.	Mit will convection correlation automa to forced convection at why low Criffo ² constituter with why low Criffo ² to constitute with appactition for APBO annulus confision. A conservative blas of 0.80 times the nominal correlation is used
Valitation of Modelling Method and/or WGOTH4C	Input Boundary Conditivor datasy lines produces a conservative rank. Earlier vaster application does not extensive import at these initiation because there is vanish that a net improvement is due to exposition and the to be exposited on a net improvement is due to exposition and the to be existent of the effect on arrendant at the effect on arrendant of the effect of the provided in provide a shift of provided in the Applications report.	WCAP 14282, p. 86 discusses validation of LST hast fits distribution predictions over the down.	Mixed convection correlation provides groot agreement with annulus contificure in the LST.
Applicability of LST with Respect to Pharmonianion	LST 219.1 has water onto hod anthree and fermiomorphic temporations those the anthrea tempty and a service the endor- provide the con- provide the con- transmission of the non- tic service and the temporation from ratio above water behavior from ratio above water behavior from ratio above water behavior from ratio above services. The observations showed that the above could be above to be above as welds services and the temporation.	LST covers range of liquid film selecoding argrected for AP00. Although a majority of the LST Although a majority of the LST reserved by selecoding the reserved by selecoding the approach for APEOD addition approach for APEOD addition approach for a scalable liquid film serve a scalable liquid film serve a scalable liquid film	Choo the outer shall heats up to at least 2F shows ambient, thread connection. LST astadiate tests afth and without ten on, consering the annihilar from miteraf test convertion domi-atted regimes.
Report Conclusions	Weak annable to PCS the same contrage fraction. PCS the state contrage fraction. PCS time datage was shown.	Inclusion of convective term in energy equation accounts to figuid Ten setocosting effect on LST dome heat fluxes.	Free connective heat transfer can be magnetized in the ADPCO files. essentish leve a mail teatine at tatal level teatine at tatal level bandlenne. See also level essention predicts the data with a connection resultion predicts the activation predicts the
Report Submitted to MPIC	MTD MFIC pol anotal WMMPIC POIS Meeting A welfere. The dimension in the topplications right will be provided in the topplications report.	Complete HECAP-14282 §2.4, 2.5 show equations for Fryad itim	Compatite MCAP-14190 MCAP-14190 Duarefiles APB00 fraction of heat removed by convective heat handler. NTDMC-15-490 MCAP-1-1205 separate affects texts vabilition WCAP-1-1205 separate affects texts vabilition
Teet Bases	- Full seals, ook	Large Scale Teels	- Haget tesh - Echant and Disputs tesh Disputs tesh - Singal and Nonta Non - Westinghouse LST - dry external host brandie
APRIO BCs or Phenomena Models	Start weeting time deby	Light film nongy conservation aquation	Moved connection correlation which reducers to the reducers to the MeMders correlation, at high Cather ²⁷ , with Cather ²⁷ , with and the correlation weight in Ga
Ransing for Read		3	
Phanetenance		C. Liquide films subcooling	O. Free connection hast transfer transfer

How Uncertainty is Handhul	Linemetery Linemetery Linemetery Linemetery Discretery	Boarded	terreter	related is under second and a second
Use of Vaktation Results in Evaluation Model	Nacional secretarian justic heliconet essentention barro, usand la secondation barro of 0.05 finner A consumption barro of 0.05 finner As normalities is used. Connected heliconet barro of a dominant lagraditand. Insert mechanism for APBOD DBA.	Concervative property values are used in AP600 DBA.	Saa hos eomendon hast konsta A omervative bias of 0.00 times the nometric constition is used	Foread convection constition, mediate la value la convection appropriate la allav instantio, la appropriate la Alla instantion A conservative bias, usoi la Meninal searchain, usoi la appropriate.
Valdation of Modelling Mathod and or WGOTHIC	WCAP: 1438C, \$3.2.1, 4.2 provide summaries of the validation. Although the comparisons with data store tight scatters (i.e. attributable to high instrument uncertularly with senal 4.1. The lack of any bread in the near over the range backeting the correlation is reasonable as a tasks threater validation. covering after an under of magnitude highle.	WEAP HERE ST shows satisfien of LET and \$3 shows validation reachs.	Res loss annociton last transfer WCAP 14382 Kennantee WOOTHC apparate afficis validation neuclis (33.2.1, 4.4)	WCAP 14392 numeratives WIGOTHIC angerrate effects validation reachs (3.2.1, 4.4)
Applications of LST with Respect to Phenomenon	Dry LST has dominant amounts heat removal by connection. The LST and separate effects heats cover the range of APB00 Reynold's numbers.	Varying fractions of day shell exitence are included for oft wet teach. The day LST cases bearefue a large fraction of heat by radiation to the battle.	See here convertion-heat barreline LST includes herb with and without from noised envolue from noised convection through thread convection through thread	LST answe angle of AUROC Gallact, insubley seals without the data rearing the data rearing ethor fain on, conserve the exotation from mixed convection through thread convection through thread convection through thread convection through thread convection at a data on weather models in an integral setting.
Raport Conclusions	Forced connection hast Creative dominates in APRO frame assessment has APRO frame assessment has been transformedian that transformedian The indust connection to indust the indust 2-5% constraints in these 0.2% constraints in these 0.2% constraints about the mean over the indust of a containt with indust of a containt with rend of a containt with rend of a containt with rend of	Dry antismual voesasi heat transfer is validated.	Reaching connection heat transfer The annulus in dominated by honed connection mass transfer once the order what up to at these 27 shows ambient during the transfer.	APBOG shown to operate the Neved convection deminant regime. Considering the strand 6 4% constrained with a strand measurable scatter over the angle and head an-0.138 an-0.138 an-0.138 an-0.138 an-0.138 an-0.138 an-0.138 an-0.138 an-0.138 an-0.138 an-0.138 an-0.138 an-0.138 an-0.138 an-0.138 an-0.138 an-0.138 an-0.138 an-0.138 and neved for provide of the angle of the analysis of the angle of the analysis of the angle of the angle of the angle of the angle of the angle of the angle of the angle of the analysis of the angle of the angle of the angle of the an
Report Submitted to NPC	Complete MCAP: 14190 Councilies APEOD Incolon of heat removed by Councilies APEOD Incolon of heat removed by WCAP: reaces, gs 1, 3 2, 5 3, 3 4, 3 5, and 4 1 there validation of the correlations with separato effects tests	Complete WCAP: 14392, §2.5 describes the radiant heat transfer model used in Climes	Complete See Jose summodien hast transfee ArtD-MRC-86-4367 Septenting Information for the Use of Foread Convection in the APSOP PCS Arrevia MCAP vet200 separate affects tests validation	Complete MTD strD: -365-43567 MTD strD: -365-43567 "Supporting Intermetion for the Ube of Foreed "Supportion" in the APBOD PCS Annutas" Complete Complete MCAP 14256 gives correlation (§2.0, 2.1), extension effect used for superstate effect test (§2.2), and correlation validation with tests (§3.6, 9.1).
Tast Bases	Huget texts Ectern and Ectern and Clagat and Nems extern and Single and Nems ext ext	Weetinghouse STC dry Net plate teets Dry LST	Othered and Shewwood engoundon lette wayoundon lette wayoundon lette wayoundon lette whenenthy of whenenthy of whenenthy of whenenthy of	 Gillianet and Starrecod Starrecod Starrecod Weakinghouse STC Mat plate STC Mat plate University of Wieconstin condomisation tests
APBOD BCs or Phenomena Microse	Minut connection constitution which constitution which entities to the column constitution at two Suffiel ²	Wall to well reditort heast brandler	Engineal correlation for the streamout number which is derived when a derived the analysis unity the Reynold's availing the derived	Employeest correlation for the strandord number, within the derived of the strandord strandord providention of a competition for more thank prove the prove
Ranking to: Rans ¹¹ Echemal Flore Path	-			I
Phancemance	E Foreid connectit: heat transfu	 F. Radiation heat transfer 	 Free convection mass transfer transfer 	H. Farrood onnection mass teache

How Uncertainty a Handfoot		prove		heginghou adlact data to weats anathrou to see anternal Klass	Conservatively properties are properties are used for APRIO containment shall
Use of Validation Reenalts in Evaluation Model		Conservatively bounded material proporties are used for AP00 adternal conductors of heat Statistics area and volume of heat underetimated. underetimated.		A 10 burged parameter model is used with an input non-inval loss coefficiant is wegoTrate analyses. Burgetory chiven flows are balanced by the form and incline losses.	10 conduction equation is part of the Clime actuologic this state barrantic through this shell. Using 10 construction from thy to wat stripes. Conservative metantial properties are used. Effects of degradefilm earneader of there of degradefilm earneader of the properties.
Vabration of Modelling Method and/or WGOTHIC		COTHIC Cualification Report shows validation for the COTHIC: 10 conductor		For lease without the tim operating, estemat flow rate and of 1 is predicted well.	WCAP 14362, §4.1 contains validables of the 1D conduction aquatitime used is Clime admostline.
Applicability of LST with Respect to Phanomenon		Address of the second sec		LST without the fan operating an applicable for validation of marine convected from through the annulue with the 1) annulus flow model.	1.D conduction: seals to model these throader throage the LST static which magnets the additional heat remove if by administic conduction from dry to wet surfaces.
Report Conclusions		Use of Ucriate for hose and relates to consumate with SRP consistent with SRP guidelinear.		For tests untrout the tim operating, enternul flow rates and 51 is provided with. Pressure response is addrively tessenative to best coefficient, since the addrively tessenative to addrive or average addrively tessenative addrively tessenative addrively tessenative addrively tessenative addrively tessenative tessenative studies terrotestes increases	The 1D conduction model is correctly programmed and WIGUTHIC
Naport Submitted to MPC		NTD ARIC da 4.200 1.2011-IC Containment Analysis Package. Vension 3 4a, Volumes 1, 96 describes th 10 conduction solution used. WCAP 44980 provides velidation with LST		Estemat flow rate and AT comparisons between WOOTHST and LST have been provided in a latter report. WITHARC 44-ENS Sensitivities to enternal Kloes, both saferun and biockages up to 50% were provided at the March 17, 1984 MRC PCS maeting. As part of the Applications report, these eventionales will be continued with analysis wave the final Evolution Model.	Complete. WCAP-14282 §2.5 shows the governing equation and decenteration for 1D conduction, as well as model validation.
Test Bases		CVTR		LST without the then expending velocities stating convective froms	Comparison to the mean that the mean that a solution at a
AP600 BCn or Phanomena Modele		GOTHIC combuction used to model a fee thereal corrected hast adds, using the COTHIC 1D condition solution		Generating aquations for threedong parameter connected with parctions	Chimes Instade 10 construction model readed for construction through construction shall
Ranting for Reserved Enternal Flow Path		x		2	I
Phanomanon	II. Northda Solida	A. 1.0 transact conduction least transfer	N. Inter-Modula	A Convertion	B. Contration

Prett	Present External	Resting APG00 BCs or for Read ¹¹ Phenemana External Microlin Flow Path	Tool Resea	Report Submitted to NRIC	Report Conclusions	Applicability of LST with Respect to Phenomenon	Validation of Modelling Method andor WGOTHEC	Use of Validationdis in Evaluation Model	How Uncertainty In Handled
C. Form and Middon Insteam	x	External flow path hydraudic resetterce	External flow path Ar flow path AP hydrautic hast, -1/5 scale resettence	Complete See also the blocks on Renes LC and MuA. See also the fine addressing from LC. "External fice path is a 10 hydraufic model."	Loan coefficient for enternal from path		LST -used constant loss coefficient Mominal loss coefficient used; look to all predictions of accethely.	Nominal loss coefficient used; lash of samethreby	Nagdigible adlect due to week seredik dy to external Kloss
				NTD-AMIC: 94-40169 Sevelabilities in enternal Rises, both uniform and non-uniform, as well as earbiting to air shalt blocklages up to 50% were provided at the March 17, 1904 MRC PCS meeting.					

Module	PIRT Phenomena	Ranking for Containment	AP600 BCs or Phenomena Models	Test Bases	Report Submitted to NR
I. Volume	A. Multi-component Compressible Gasses	Η	Gas constituents in the governing equations	All tests analyzed with WGOTHIC	Complete NTD-NRC-94 4260 Enclosure 1: GOTHIC Technical Manual describe governing equations Enclosure 2: GOTHIC User's Manual describes how to invoke various gasses Enclosure 3: GOTHIC Qualification Report provides large database of tests with air, hydrogen, and helium NTD-NRC-95-4462 EPRI Report RA-93-10, GOTHIC Design Review, Final Report WCAP-14382 validates WGGTHIC with separate effects, integral tests with steam and air, and helium
	B. Buoyancy	Н	Buoyancy forces are included in the lumped parameter junction governing equations	LST internal boouyant flows Hugot tests Siegel & Norris tests	Complete WCAP-14326, Separate effects test WCAP-14382, for integral tests

Table 1: PIRT Application to Evaluat

Page 1 of 6

ANSTEC APERTURE CARD Also Available on Aperture Card

Report Conclusions	Applicability of LST with Respect to Phenomena	Validation of Modeling Method and/or WGOTHIC	Use of Validation Results in this Evaluation Model	How Uncertainty is Handled
Effects of multicomponent compressible gasses are correctly included in governing equations	LST includes air and steam, and helium	WGOTHIC has been validated with the LST	Governing equations in WGOTHIC are a valid representation of compressible, multicomponent gas behavior Maximum Technical Specification pressure used in conjunction with 0% relative humidity.	Bounded
Lumped modeling overmixes noncondensibles above operating deck thereby reducing heat removal from vessel when PCS is dominant Distributed parameter modeling shows good agreement with 550 node LST model. Modeling of buoyancy and entrainment is acceptable.	Steam injection point elevation and direction effects tests were performed LST has prototypical buoyancy driving forces and covered the range of Froude numbers for LOCA	WGOTHIC has been validated with the LST	Mixing and stratification resulting from buoyancy- driven flow will be studied in the WGOTHIC- Applications WCAP See boxes for line IV.A.	Sensitivity to mixing- will be provided in applications WCAP Bounded

Model: Inside Containment - All phases

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Table 1: PIRT Application to Evaluat

Module	PIRT Phenomena	Ranking for Containment	AP600 BCs or Phenomena Models	Test Bases	Report Submitted to NR
	C. Flow Field Stability or Stratification	L	Mixing within the containment upper regions and mixing between the upper and lower portions of the containment	LST	NTD-NRC-95-4459, Stratification and Mixing Effects on AP600 Passive Containment Cooling System DBA WGOTHIC Applications Document ACRS T/H Subcommittee Meeting, March 29-30, 1995 (to be documented in letter report)
II. Surface	A. Liquid Film Heat Transfer	М	Thermal conductivity of liquid film for film temperature drop	Chun & Seban Wisconsin Condensation Tests	Complete NTD-NRC-94-4100, Enclosure 2 "Liquid Film Model Validations" WCAP-14382 §2
	B. Liquid Film Stability/Coverage	L	Condensation on the interior surface of containment	LST Wisconsin Condensation Tests	WCAP-13307 I.K. Huhtininemi, "Condensation in the Presence of Noncondensib Gas: Effect of Surface Orientation," Ph.D. Thesis Univ. Wisconsin, 1992
	C. Liquid Film Enthalpy Transport	М	Liquid film energy conservation equation	LST Wisconsin Condensation Tests	Complete WCAP-14382 §2.4, 2.5 show equations for liquid film WCAP-14190

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ANSTEC APERTURE CARD

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Report Conclusions	Applicability of LST with Respect to Phenomena	Validation of Modeling Method and/or WGOTHIC	Use of Validation Results in this Evaluation Model	How Uncertainty is Handled
Blowdown is the same as standard plants. Long-term LOCA is driven by buoyant plume and L3T covers range for AP600. MSLB is well mixed due to high velocity jet. Distributed parameter modeling shows good agreement with 550 node LST model. Modeling of buoyancy and entrainment is acceptable.	Upper and lower regions of containment represented in the LST	WGOTHIC model has been validated with the LST	Mixing and stratification resulting from buoyancy- driven flow will be studied in the WGOTHIC- Applications WCAP See boxes for line IV.A	Sensitivity to mixing and break size will be provided in applications WCAP Bounded
The Chun and Seban data provides a basis for film thermal conductivity.	Internal and external liquid film effects are represented in the LST	All validation performed with WGOTHIC includes the small effect of film temperature drop	Nominal wavy-laminar and turbulent Chun and Seban correlations used as appropriate	Negligible effect since resistance across film is small part of total resistance
Internal films are stable since containment shell slope is in excess of 1°. Droplet formation improves mass transfer	Prototypical surfaces included in the LST Separate effects studied in Wisconsin Condensation Tests	WGOTHIC model has been validated with the LST	Shell slopes modeled with WGOTHIC exceed 1" Condensate on containment is returned to the IRWST Benefits of droplet formation neglected	Bounded
Subcooling is negligible compared to energy transported to liquid field	Prototypical surfaces included in the LST Separate effects studied in Wisconsin Condensation Tests	WGOTHIC model has been validated via the LST and Wisconsin Condensation Tests	Temperature profile through film considered in solution	Negligible, film is at or near saturation temperature

on Model: Inside Containment - All phases

Date Last Modified: August 29, 1995 4:09 pm

Table 1: PIRT Application to Evalua

Module	PIRT Phenomena	Ranking for Containment	AP600 BCs or Phenomena Models	Test Bases	Report Submitted to NR
	D. Free Convection Heat Transfer	L	McAdams Flat Plate Correlation Mixed Convection	LST	WCAP-14190 page 2-7 WCAP-14326 page 4-1 WCAP-14382 §8
	E. Forced Convection Heat Transfer	L	Lumped - Not modeled Distributed - flat plate forced convection, mixed convection	LST	WCAP14190 page 2-7 WCAP-14326 page 4-1 WCAP-14382 §8
	F. Radiation Heat Transfer	L	Not modeled	LST	WCAP-14190 page 2-8
	G. Free Convection Mass Transfer	Н	Lumped - Heat and mass transfer analogy based on McAdams flat plate heat transfer correlation Distributed - Heat and mass transfer analogy using the mixed convection correlation	LST Wisconsin Condensation Tests	WCAP-14190 page 2-8 WCAP-14326 §3.8, 3.9, 4 WCAP-14382 §4.3, 8.2
	H. Forced Convection Mass Transfer	L	Lumped - Not modeled Distributed - Heat and mass transfer analogy- based on flat plate forced convection in the mixed convection correlation	LST Wisconsin Condensation Tests	WCAP-14190 page 2-8 WCAP-14326 §3.8

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on Model: Inside Containment - All phases

Report Conclusions	Applicability of LST with Respect to Phenomena	Validation of Modeling Method and/or WGOTHIC	Use of Validation Results in this Evaluation Model	How Uncertainty is Handled
<i>Convective</i> heat transfer is not significant in comparison to mass transfer	Prototypical internals Range of validation defined in WCAP- 14382 §9.2	WGOTHIC model has been validated with the LST	A conservative bias of 0.741 times the nominal correlation is used	Bounded by conservative bias
Convective heat transfer is not significant in comparison to mass transfer	Prototypical internals Range of validation defined in WCAP- 14382 §9.2	WGOTHIC model has been validated with the LST	Lumped - Forced convection heat transfer not considered Distributed - Nominal flat- plate correlation	Lumped - Bounded by neglecting forced convection Distributed Bounded by code- uncertainty
Temperature differences within containment are small enough that "adiative heat transfer is low	Prototypical internals and temperature driving forces modeled in LST	WGOTHIC modeling of LST neglected radiative heat transfer	Not modeled	Bounded
Mass transfer conservatively biased mean=0.983 σ=0.187	Prototypical internals and temperature driving forces modeled in LST Range of validation defined in WCAP- 14382 §9.2LST internal data as a separate effect Wisconsin Condensation TestsA conservative bias of 0.74 times the nominal correlation is used		and a set of the set o	Bounded by conservative bias
Mass transfer conservatively biased mean=0.968 σ=0.203	Prototypical internals and Froude numbers modeled in LST Range of validation defined in WCAP- 14382 §9.2	Lumped - Validated WCAP- 14382 §8 Dominant only during first sec of LOCA transient Disconted - Dominant only- during first seconds of transient	Lumped - Not modeled Distributed - Mixed convection correlation convection and forced convection with a conservative hies	Bounded by neglecting forced convection

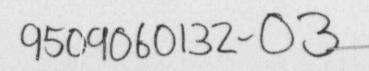


Table 1: PIRT Application to Evalua

Module	PIRT Phenomena	Ranking for Containment	AP600 BCs or Phenomena Models	Test Bases	Report Submitted to NR
III. Solids	A. i-D Transient Conduction Heat Transfer	Н	GOTHIC conductors used to model internal heat sinks include a 1-D conduction solution	CVTR LST with internal heat sinks	NTD-NRC-94-4260 "GOTHIC Containment Analysis Package, Versiot 3.4e, Volumes 1-111," Volume 1, §6 describes th 1-D conduction solution used. WCAP-14382 provides validation with LST



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on Model:	Inside	Containment		All	phases
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Report Conclusions	Applicability of LST with Respect to Phenomena	Validation of Modeling Method and/or WGOTHIC	Use of Validation Results in this Evaluation Model	How Uncertainty is Handled
Use of Uchida with 1-D conductor for internal heat sinks is conservative and consistent with SRP guidelines	Internal LST heat sinks are modeled using GOTHIC conductors with Uchida for condensation	WCAP-14382 shows validation results with internal heat sinks modeled with Uchida	SRP guidelines are an acceptable approach. Conservatively bounded material properties are used for AP600 internal conductors. Surface area and volume of internal heat sinks are conservatively underestimated.	Bounded

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Table 1: PIRT Application to Evalua

Module	PIRT Phenomena	Ranking for Containment	AP600 BCs or Phenomena Models	Test Bases	Report Submitted to NR
IV. Inter- Module	A. Convection	L	Governing equations for lumped parameter volumes connected with junctions and node-to-node connections for distributed parameter	LST	NTD-NRC-95-4459, Stratification and Mixing Effects on AP600 Passive Containment Cooling System DBA WCAP-14382 §5.3 WGOTHIC Applications Document WCAP-14190 §9



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Report Conclusions	Applicability of LST with Respect to Phenomena	Validation of Modeling Method and/or WGOTHIC	Use of Validation Results in this Evaluation Model	How Uncertainty is Handled
Fr scaling shows MSLB expected to be well mixed. Flow area restriction in evaluation model limits steam access to below deck during short MSLB releases Lumped - Overmixing penalizes heat and mass transfer when PCS is dominant (LOCA longterm) Distributed - 375 node LST is sufficiently- accusate with has slight bias towards overmixing - can bias mixing with flow areas LOCA blowdown pressurizes SG compartment sufficiently to drive flow throughout lower compartments. Natural circulation develops post-blowdown	Applicable to above deck circulation and heat and mass transfer correlation validation LST has been used to develop rationale for bounding approach on mixing	Mixing biased toward worst case for each accident. A sensitivity using nominal flow area in the AP6G0 will be provided in the Applications WCAP to quantify conservative bias.	Restrict mixing between upper and lower regions of containment when mixing is a benefit (LOCA second peak)	Bounded by biasing mixing in conservative direction for each accident

Model: Inside Containment - All phases

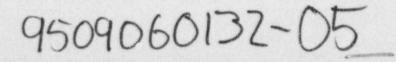


Table 1: PIRT Application to Evaluat

Module	PIRT Phenomena	Ranking for Containment	AP600 BCs or Phenomena Models	Test Bases	Report Submitted to NR
	B. Conduction	Н	Climes include 1-D conduction model used for conduction through containment shell	Comparison to theoretical solutions	Complete. WCAP-14382 §2.5 shows the governing equation and discretization for 1-D conduction
	C. Form and Friction Losses	L	Inter-compartment losses	Standard experimentally based loss coefficients	WCAP-14382 §6.0 describes methods used to model LST

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Report Conclusions	Applicability of LST with Respect to Phenomena	Validation of Modeling Method and/or WGOTHIC	Use of Validation Results in this Evaluation Model	How Uncertainty is Handled
The 1-D conduction model is correctly programmed into WGOTHIC	1-D conduction used to model heat transfer through the LST shell, which neglects the additional heat removal by azimuthal conduction from dry to wet surfaces.	WCAP-14382 §4.1 contains validation of the 1- D conduction equations in Clime subroutine	1-D conduction equation is part of the Clime subroutines used for heat transfer through the shell. Effects of degradation of inorganic zinc paint are included in material properties. Conservative material properties used. Using 1-D conduction conservatively neglects azimuthal conduction from dry to wet stripes.	Bounded
Use of standard loss coefficients through grating is validated	Simplified representation of lower compartments	See IV.A.	Restrict mixing between upper and lower regions of containment when mixing is a benefit. Increase mixing when it is a penalty. (See IV.A.)	Bound effects of mixing.

n Model: Inside Containment - All phases

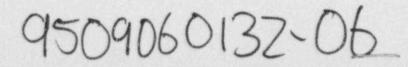


Table 2: PIRT Application to Evaluation Model: Outside Containment - LOCA - All Phases

PIRT Phenomenon	Ranking for Risor⁽⁴⁾ External Flow Path	AP600 BCs or Phenomena Models	Test Bases	Report Submitted to NRC	Report Conclu
I. Module Volum	10				
A. Multi- component compressible gasses	н	Gas constituents in the governing equations	All tests analyzed with WGOTHIC	Complete NTD-NRC-94-4260 Enclosure 1: GOTHIC Technical Manual ⁴ describes the governing equations Enclosure 2: GOTHIC User's Manual describes how to invoke various gasses Enclosure 3: GOTHIC Qualification Report provides a large database of tests with air, hydrogen, and helium. NTD-NRC-95-4462 EPRI Report RA-93-10, GOTHIC Design Review, Final Report WCAP-14382 validates WGOTHIC with separate effects and integral tests with steam, air, and helium gases. *Revision will be made to correct typographical errors. *Westinghouse will expedite revised documentation which addresses Peer Review results.	Effects of mult component co gasses are co included in go equations.
B. Buoyancy	н	Buoyancy forces are included in the lumped parameter - junction governing equations	LST without fan running Hugot tests Eokert and Diaguila teste Siegel and Norris tests	Complete WCAP-14382 §7.2.2 identifies the relevant priority teet LST with fan off to support external annulus modelling. WCAP-14326 § 3.1, 3.3 NTD-NRC-94-4083 <u>W/NRC PCS Meeting</u> To be issued: As part of the Applications Report, Decument the sensitivity to Kloss (uniform and nonuniform) and nominal delay time will be confirmed using the final evaluation model.	The external predictions pr comparisons reasonable and with LST-and uncortaintice accommodate DBA. External seps with buoyanc flows are valid Weak sensitive (uniform and has been sho



		Date last modified: August 28	Altec	Available on erture Card
5	Applicability of LST with Respect to Phenomenon	Validation of Modelling Method and/or WGOTHIC	Use of Validation Results in Evaluation Model	How Uncertainty is Handled
	LST includes air, steam, and	WCAP-14382 provides validation of	Governing equations in WGOTHIC	Included in code
essible lly ing	helium.	external annulus modelling methods.	are a valid representation of compressible, multi-component gas behavior. Maximum Tech Spec value of environment temperature is used as the boundary condition in WGOTHIC models.	uneertainty Bounded
alus e ment eciated be the i effects iven id. to Kloss uniform)	All 7 baseline and 7 confirmatory LST in the HWRF program were run with the fan off. The LST priority test 214.1 (fan off) has been used for validation.	WGOTHIC has been validated with LST 214.1 with natural convection driving the annulus flows in WCAP- 14382 §5, 6, 7, 8.	The external annulus is modelled with pressure boundary conditions at the inlet and outlet, such that the imposed ΔP is ≤ equal to the external density head driving force. Thus, the initial annulus air flow is conservatively established at a <i>slightly</i> negative value (directed downward in the annulus). The momentum equation is solved, balancing the buoyancy driving head with the unrecoverable losses through the annulus.	Nominal loss coefficient is used. Weak sensitivity to loss coefficient Conservative initial air flow bounds postulated annulus flow start-up concerns

PIRT Phenomenon	Ranking for Risor⁽¹⁾ External Flow Path	AP600 BCs or Phenomena Models	Test Bases	Report Submitted to NRC	Report Coriclu
C. Flow field stability or stratification	L	External flow path is a 1D hydraulic model	 LST riser External flow path △P test Eckert and Diaguila Siegel and Norris Hugot 	Complete NTD-NRC-95-4414 RAI 952.102 response: WCAP-14190, Section 7.2 and 7.3 provide momentum and energy scaling for justification. WCAP-14382, §8 provides validation using 1D flow path for annulus. To be issued: Applications Report Decument sensitivity to Kloss (uniferm and nonuniform) and nominal delay time. See block on line above for loss coefficient study results.	Potential for low recirculation at downcomer ink total air flow at operating cond negligible since minimal energy momentum in t downcomer. Small sensitivit large Kloss effe
	•	Fog in annulus	-	Complete NTD-NRC-94-4100, Enclosure 1 "Radiation Heat Transfer Through Fog in the PCCS Air Gap"	Justification for effect of fog in since effect of capture by fog has a negligible the annulus air temperature ar overestimates transfer to the
	*	Effect of wind- induced recirculation and stratified atmosphere is neglected	Literature	Complete NTD-NRC-94-4166 "AP600 Containment Plume Investigation"	Quantification of for recirculation and thermally s atmosphere to cooling rates g bounding recirc fraction, and a sensitivity show significant cont pressure effect
		Effect of wind- induced turbulence is neglected	Wind tunnel tests	Complete. NTD-NRC-95-4467 "Analysis of AP600 Wind Tunnel Testing for PCS Heat Removal"	Oscillating flow case site with I positive mean coefficient sligh increase heat in rates from con Less severe te more positive si coefficients she significant incre heat removal.

6	Applicability of LST with Respect to Phenomenon	Validation of Modelling Method and/or WGOTHIC	Use of Validation Results in Evaluation Model	How Uncertainty is Handled
o affect 600 hs is ere is	N/A Successful modelling of the external annulus with a 1D flow path shows ability of 1D model to predict riser phenomena.	The downcomer flow area is large to act as a reservoir within which pressures can equalize, providing a relatively uniform inlet for the annulus. Use of 1D flow path is justifiable Since heat transfer and momentum in the downcomer, relative to the riser, is so small that the possibility of downcomer instabilities is insignificant. Flow is primarily one-dimensional in nature; therefore, use of 1D flow path is justifiable. Since fully developed turbulent flow develops in annulus before the baffle heats up, there is no potential for hot-baffle-induced flow instability to impact impact on start-up of annulus air flow.	External flow path is modelled as 1D lumped parameter ANSTEC APERTURE CARD Also Available on Aperture Card	Negligible effect Weak sensitivity to external loss coefficient shows pressure is not sensitive to postulated inhibitors to external flow.
glecting hulus lation AP600 fect on heat Ne.	Database consistent with AP600 expectations for external annulus conditions.	Effect of fog neglected in WGOTHIC models	Negligible effect on answers	Negligible effect
octential effluent tified ect ation sulting I no iment	LST was run in no-wind (<5 mph) conditions	External pressure boundary condition is unadjusted for these effects	Assumption of no recirculation due to these effects has negligible impact on pressure prediction	Negligible effect
or worst st wo noval mment. ins with d wes in	Not applicable	External pressure boundary condition is unadjusted for these effects	Assumption of no wind is bounding for pressure prediction	Bounded

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PIRT Phenomenon	Ranking for Risor⁽¹⁾ External Flow Path	AP600 BCs or Phenomena Models	Test Bases	Report Submitted to NRC	Report Conclus
II. Module Surface	•				
A. Liquid film heat transfer	м	Thermal conductivity of liquid film for film temperature drop.	Chun and Seban	Complete NTD-NRC-94-4100, Enclosure 2 "Liquid Film Model Validation" WCAP-14382 §2 Scaling supplement will document consistent definition of resistances inside to outside shell	The Chun and data provides of film thermal co The liquid film temperature dr
B. Liquid film stability/coverage	H	Sheli water coverage fractions and applied flow rate	 Full scale, cold 1/8 sector tests Hot LST measured coverage Westinghouse flat plate evaporation tests Vendor age/contamination information tests 	Complete. WCAP-12665, §3.1 NTD-NRC-94-4247 "Method for Determining Film Flow Coverage for the AP66.2 Passive Containment Cooling System" NTD-NRC-94-4286 "Supplemental Information on AP600 PCS Film Flow Coverage Methodology," <i>including</i> sensitivity to 3/4 and 1/2 of bounding SSAR coverages showing well away from any cliffs in performance. SSAR Rev. 4 Preliminary Markup 6.2.1.1.3 summarizes water coverage assumptions. NTD-NRC-94-4083 W/NRC PCS Meeting Weak sensitivity to PCS flow rate, water coverage fraction, PCS time delay was show n. To be issued: Vendor report on offects of age and contamination. Note: An independent review by an industry export is also planned.	Tests with wat surfaces up to showed that th without delay, quenching a hi cold water. Ex films do not be unstable, even film dryout. Water coverag and sidewalls i function of time bound (Figure scale data and data from LST model has bee with cold and I tests, and bound data. Model adequai conservatively for effects of a using a via its- the wetting any new surface. increases the p the surface any increases wett Surface contait be minimal bea inspection and criteria. Sensi using approxim and 1/2 and 44 bounding SSA values show th AP600 pressur is relatively ins further reductio coverage belo bounding mini-

	Applicability of LST with Respect to Phenomenon	Validation of Modelling Method and/or WGOTHIC	Use of Validation Results in Evaluation Model	How Uncertainty is Handled
in is for tivity. small.	Internal and external liquid film effects are represented in the LST.	All validation performed with WGOTH:C includes the small effect of tilm temperature drop.	Nominal Chun and Seban correlation is used, accounting for wavy laminar and turbulent liquid films.	Negligible effect since resistance across film is small part of total resistance.
to the well the with ating e total dome ised to skd, full ated e lidated d e lidated od est by st-on or a g ity of is on aning es ly 3/4 overage he isponse titive to in est	Heated LST data has been used to assees heat flux effect on coverage fractions on the LST were used as input boundary conditions in the WGOTHIC validation runs to validate cooling rate prediction models with test data.	Water coverage is an input boundary condition to the WGOTHIC code. A "top-to-bottom stack" of climes is used to model each of the wetted and dry portions of the external shell. Coverage fractions are used to determine the maximum value of potentially wetted shell heat transfer surface area input to the WGOTHIC climes model. Coverage for the dome at top and mid levels is assumed to be 40% to bound full scale cold test data, where the film is thick enough that film stability does not limit coverage. The wetted cross sectional area of the balance of the wetted portion where film stability limits coverage is obtained from 26.17 hrs in Table 4 of NTD-NRC-94-4247, where 100% dome coverage values show that film stability does not limit dome coverage. The Table 4 values have not been adjusted to account for the reduced evaporation associated with the assumed 40% coverage on the dome. Therefore, the coverage fraction assumed in the DBA bounds all times during the PCS DBA. Weak sensitivity to the input water coverage shows that minor perturbations in this assumption do not impact pressure predictions.	<text><text><text><text></text></text></text></text>	Bounded

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PIRT Phenomenon	Ranking for Riser ⁽¹⁾ External Flow Path	AP600 BCs or Phenomena Models	Test Bases	Report Submitted to NRC	Report Concli
		Shell wetting time delay	Full scale, cold 1/8 sector tests	NTD-NRC-94-4083 <u>W</u> /NRC PCS Meeting A-written-The discussion in the boxes to the right will be provided in the applications report.	Weak sensitiv flow rate, wat fraction, PC3 was shown
C. Liquid film subcooling	M	Liquid film energy conservation equation	Large Scale Tests	Complete WCAP-14382 §2.4, 2.5 show equations for liquid film	Inclusion of o term in energ accounts for I subcooling ef dome heat flu
D. Free convection heat transfer	L	Mixed convection correlation which reduces to the McAdams correlation, at high Gr/Re ^{2,7} , with characteristic length in Gr number based on channel diameter	 Hugot tests Eckert and Diaguila tests Siegel and Norris tests Westinghouse LST - dry external heat transfer 	Complete WCAP-14190 Quantifies AP600 fraction of heat removed by convective heat transfer. NTD-NRC-95-4397 Supporting Information for the Use of Forced Convection in the AP600 PCS Annulus WCAP-14326 separate effects tests validation	Free convecti transfer can b in the AP600 accounts for traction of tet transferved. See also fore convection he The mixed co correlation pr data with a c mean bias of

5	Applicability of LST with Respect to Phenomenon	Validation of Modelling Method and/or WGOTHIC	Use of Validation Results in Evaluation Model	How Uncertainty is Handled
PCS vərage dəlay	LST 219.1 has water onto hot surface and thermocouple temperatures show the surface readily rewets during the high flow portion of the non- prototypical oscillating flow. Videotapes of a shakedown LST with a somewhat higher flow rate show water behavior applied to 240F surface. The observations showed that the advancing film front sizzled as it was boiled away, and readily flowed down as wide stripes after the surface fell below the leidenfrost temperature.	Input Boundary Condition delay time produces a conservative result. Earlier water application does not adversely impact air flow initiation because there is would be a net improvement in due to evaporative cooling. The effect on annulus air temperature and vapor content of water applied to the surface is explicitly modeled in WGOTHIC 1D annulus calculation. A sensitivity based on actual chronology with earlier wetting will be provided in the Applications report.	Since the outer surface temperature does not increase significantly is not hot until after water reaches the containment shell surface in real time, cold tests are acceptable to determine delay times. Delay time to wet the external surface is conservatively bounded by using time to reach steady state coverage fractions from the cold full scale test. This conservative delay time thus neglects integrated heat removal during about 10 5 minutes of actual water application during the period when steady state film coverage is developing, when surface temperature has not eignificantly increased. Time delay used bounds all postulated effects	Bounded ANSTE APERTU CARD Also Available Aperture Ca
ctive uation I film on LST	LST covers range of liquid film subcooling expected for AP600. Although a majority of the LST have higher fractions of energy removed by subcooling than AP600, the LST is valid for <i>developing a bounding</i> <i>approach for AP600</i> validation of physics and phenomena since a scalable liquid film enthalpy transport model is used.	WCAP-14382, p. 8-6 discusses validction of LST heat flux distribution predictions over the dome.	WGOTHIC uses an appropriate set of governing equations for liquid film. Subcooling accounts for a small fraction (~5%) of the AP600 heat removal.	Negligible effect since mechanism accounts for only small fraction of AP600 heat removal.
eat eglected r. all eat ransfer action ats the ervative	Once the outer shell heats up to at least 2F above ambient, the AP600 annulus operates in forced convection. LST includee tests with and without fan on, covering the annulus from mixed f.ee convection through forced convection dominated regimes.	Mixed convection correlation provides good agreement with annulus conditions in the LST.	Mixed convection correlation reduces to forced convection at high <i>low</i> Gr/Re ^{2.7} , consistent with expectation for AP600 annulus conditions. A conservative bias of 0.83 times the nominal correlation is used.	Negligible offect Bounded

PIRT Phenomenon	Ranking for Riser⁽¹⁾ External Flow Path	AP600 BCs or Phenomena Models	Test Bases	Report Submitted to NRC	Report Conclu
E. Forced convection heat transfer	L	Mixed convection correlation which reduces to the Colburn correlation at low Gr/Re ^{2.7}	 Hugot tests Eckert and Diaguila tests Siegel and Norris tests Westinghouse STC dry flat plate tests Westinghouse LST - dry external heat transfer 	Complete WCAP-14190 Quantifies AP600 fraction of heat removed by convective heat transfer. WCAP-14326, §3.1, 3.2, 3.3, 3.4, 3.5, and 4.1 shows validation of the correlations with separate effects tests	Forced convex transfer domin AP600 riser, a a small fraction heat transferred The mixed con- correlation is to conservative a mean over the a relatively lar due to large m uncertainty viri $\mu = 0.976$ $\sigma = 0.278$
F. Radiation heat transfer	L	Wall-to-wall radiant heat transfer	Westinghouse STC dry flat plate tests Dry LST	Complete WCAP-14382, §2.5 describes the radiant heat transfer model used in Climes	Dry external v transfer is vali
G. Free convection mass transfer		Empirical correlation for the Sherwood number, which is derived by dimensional analysis using the Reynold's analogy and Colburn j factors.	Gilliland and Sherwood evaporation tests Westinghouse STC flat plate evaporation tests University of Wisconsin condensation tests	Complete See free convection heat-transfer NTD-NRC-95-4397 Supporting Information for the Use of Forced Convection in the AP600 PCS Annulus WCAP-14326 separate effects tests validation	See free corv transfer The annulus i by forced con mass transfer outer shell he least 2F abov during the tra
H. Forced convection mass transfer	H	Empirical correlation for the Sherwood number, which is derived by dimensional analysis using the Reynold's analogy and Colburn j factors. <i>Application of a correction for</i> mass transfer rate gives the AP600 forced convection mass transfer correlation	Gilliland and Sherwood evaporation tests Westinghouse STC flat plate evaporation tests University of Wisconsin condensation tests	Complete. NTD-NRC-95-4397 "Supporting Information for the Use of Forced Convection in the AP600 PCS Annulus" Complete. WCAP-14326 gives correlation (§2.0, 2.1), entrance effect used for separate effect test (§2.2), and correlation validation with tests (§3.6, 3.7).	AP600 shown in forced conv dominant regi Correlation is conservative of reasonable so the range. $\mu = 0.936$ $\sigma = 0.139$ Once the out up to at least ambient, the forced convex

	Applicability of LST with Respect to Phenomenon	Validation of Modelling Method and/or WGOTHIC	Use of Validation Results in Evaluation Model	How Uncertainty is Handled	
heat in ste for stal ion d 2.4% the ge, with atter irement iall ΔT .	Dry LST has dominant ar:nulus heat removal by convection The LST and separate effects tests cover the range of AP600 Reynold's numbers.	WCAP-14382, §3.2.1, 4.2 provide summaries of the validation. Although the comparisons with data show high scatter, it is attributable to high instrument uncertainty with small ΔT . The lack of any trend in the mean over the range indicates the correlation is reasonable as a basis for mass transfer analogy. Mass transfer validation, covering ΔT an order of magnitude higher, shows much less scatter.	Nominal correlation (with inherent concervative bias) used in WGOTHIC. A conservative bias of 0.83 times the nominal correlation is used. Convective heat transfer is not a dominant significant- heat removal mechanism for AP600 DBA.	p.	NSTEC ERTURE CARD
l heat £	Varying fractions of dry shell surface are included for all wet tests. The dry LST cases transfer a large fraction of heat by radiation to the baffle.	WCAP-14382 §7 shows selection of LST and §8 shows validation results.	Conservative property values are used in AP600 DBA.	Bounded Ap	erture Card
n heat ninated on e the p to at ibient it.	See free convection heat transfer LST includes tests with and without fan on, covering the anculus from mixed convection through forced convection dominated regimes.	See free convection heat transfer WCAP-14382 summarizes WGOTHIC separate effects validation results (§3.2.1, 4.4)	See free convection heat transfer A conservative bias of 0.83 times the nominal correlation is used.	Nogligible offect Bounded	
perate m ed 6.4% over ell heats bove to in	LST covers range of AP600 Gr/Re2, including tests without the fan running LST includes tests with and without fan on, covering the annulus from mixed convection through forced convection dominated regimes. WCAP-14382 LST includes tests which cover range of AP600 subcooling; Predictions of total evaporation (p. 8-3) and wall heat itux (p. 8-6) validate models in 25 integral soiting.	WCAP-14382 summarizes WGOTHIC separate effects validation results (§3.2.1, 4.4)	Forced convection correlation, modified for mixed convection effects to allow transient startup, is appropriate for AP600. A conservative bias of 0.83 times the nominal correlation is used. Nominal correlation (with inhorent conservative bias) used in WGOTHIC.	Included in code uncortainty (coattor) is incorporated as an element of code uncortainty. Bounded	

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III. Module Sciids	1				
A. 1D transient conduction heat transfer	H	GOTHIC conductors used to model a few external concrete heat sinks, using the GOTHIC 1D conduction solution	CVTR	NTD-NRC-94-4260 "GOTHIC Containment Analysis Package, Version 3.4e, Volumes I-III," Volume 1, §6 describes the 1D conduction solution used. WCAP-14382 provides validation with LST	Use of Uchida sinks is consar consistent with guidelines.
IV. Inter-Mod					
A. Convectori	м	Governing equations for lumped parameter volumes connected with junctions	LST without the fan operating validate ability to calculate natural convective flows	 External flow rate and ∆T comparisons between WGOTHIC and LST have been presented at several meetings. These will be provided in a letter report. <i>NTD-NRC-94-4083</i> Sensitivities to external Kloss, both uniform and non-uniform, as well as sensitivity to air inlet blockages up to 50% were provided at the March 17, 1994 NRC PCS meeting. As part of the Applications report, these sensitivities will be confirmed with evaluated using the final Evaluation Model. 	For tests witho operating, exter rate and ∆T is well. Pressure response relatively insen loss coefficient system is self- The highly non celation of evap rate with surfact temperature re- increased evap cooling with or moderato surfac- temperature in
B. Conduction	H	Climes include 1D conduction model used for conduction through containment shell	Comparison to theoretical £ lutions	Complete. WCAP-14382 §2.5 shows the governing equation and discretization for 1D conduction, as well as model validation.	The 1D condu is correctly pro into WGOTHIC

	Applicabilit, of LST with Respect to Phenomenon	Validation of Modelling Method and/or WGOTHIC	Use of Validation Results in Evaluation Model	How Uncertainty is Handled
hwat re and p	Not applicable	GOTHIC Qualification Report shows validation for the GOTHIC 1D conductor.	Conservatively bounded material properties are used for AP600 external conductors Surface area and volume of heat sinks are conservatively underestimated.	Bounded ANSTE APERTU CARD Aperture Car
	<u> </u>			
he fan flow dicted e is é to nce the scting. har ition s in tive	LST without the fan operating ar a applicable for validation of - atural convective flows through the annulus with the 1D annulus flow model.	For tests without the fan operating. external flow rate and ∆T is predicted well.	A 1D lumped parameter model is used with an input nominal loss coefficient in WGOTHIC analyses. Buoyancy driven flows are balanced by the form and friction losses.	Negligible effect due to weak sensitivity to external Kloss
uses.				Orenegatively
n model mmed	1D conduction used to model heat transfer through the LST shell, which neglects the additional heat removal by azimuthai conduction from dry to wet surfaces.	WCAP-14382, §4.1 contains validation of the 1D conduction equations used in Clime subroutines.	1D conduction equation is part of the Clime subroutines used for heat transfer through the shell. Using 1D conduction conservatively neglects azimuthal conduction from dry to wet stripes. Conservative material properties are used. Effects of <i>degradation</i> correction_of inorganic zinc paint are included in	Conservatively bounded material properties are used for AP600 containment shell.

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C. Form and friction losses	н	External flow path hydraulic resistance	Air flow path ∆P test, ~1/6 scale	Complete See also the blocks on items I.C and IV.A. See also the line addressing item I.C. "External flow path is a 1D hydraulic model." NTD-NRC-94-4083 Sensitivities to external Kloss, both uniform and non-uniform, as well as sensitivity to air inlet blockages up to 50% were provided at the March 17, 1994 NRC PCS meeting.	Loss coefficien external flow p

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Applicability of LST with Respect to Phenomenon	Validation of Modelling Method and/or WGOTHIC	Use of Validation Results in Evaluation Model	How Uncertainty is Handled
	LST - used constant loss coefficient for all predictions	Nominal loss coefficient used; lack of sensitivity	Negligible effect due to weak sensitivity to external Kloss



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